### Functional Groups and Structures

1. Which is NOT a correct Lewis structure?

   A) \( \begin{array}{c} \text{H} \end{array} \quad \begin{array}{c} \text{N} \end{array} \quad \begin{array}{c} \text{F} \end{array} \quad \begin{array}{c} \text{H} \end{array} \quad \begin{array}{c} \text{H} \end{array} \)  
   B) \( \begin{array}{c} \text{H} \end{array} \quad \begin{array}{c} \text{C} \end{array} \quad \begin{array}{c} \text{F} \end{array} \quad \begin{array}{c} \text{H} \end{array} \)  
   C) \( \begin{array}{c} \text{H} \end{array} \quad \begin{array}{c} \text{O} \end{array} \quad \begin{array}{c} \text{O} \end{array} \quad \begin{array}{c} \text{H} \end{array} \)  
   D) \( \begin{array}{c} \text{O} \end{array} \quad \begin{array}{c} \text{H} \end{array} \quad \begin{array}{c} \text{H} \end{array} \)  
   E) None of these

   Ans.: A

2. Which of the following represent pairs of constitutional isomers?

   A) \( \begin{array}{c} \text{CH}_3\text{CH}_2\text{COH} \quad \text{and} \quad \text{CH}_3\text{COCH}_3 \end{array} \)  
   B) \( \begin{array}{c} \text{Cl} \quad \text{H} \quad \text{H} \quad \text{Cl} \quad \text{Cl} \)  
   C) \( \begin{array}{c} \text{Cl} \quad \text{H} \quad \text{Cl} \quad \text{C} \quad \text{C} \)  
   D) More than one of these pairs
   E) All of these pairs

   Ans.: D

3. In which structure(s) below does nitrogen have a formal charge of +1?

   \( \begin{array}{c} \text{H} \quad \text{CH}_3\text{N=CH}_2 \quad \text{CH}_3\text{N-H} \quad \text{N-OH} \quad \text{CH}_3\text{NH}_2 \quad \text{CH}_3\text{N-CH}_3 \end{array} \)

   \( \begin{array}{c} \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \quad \text{V} \end{array} \)

   Ans.: I
4. The bond angles in PH$_3$ would be expected to be approximately:
   A) 60°
   B) 90°
   C) 105°
   D) 109°
   E) 120°

Ans.: D

5. The compound shown below is a synthetic estrogen. It is marketed as an oral contraceptive under the name Enovid.

![Chemical Structure](image)

In addition to an alkane (actually cycloalkane) skeleton, the Enovid molecule also contains the following functional groups:
   A) Ether, alcohol, alkyne.
   B) Aldehyde, alkene, alkyne, alcohol.
   C) Alcohol, carboxylic acid, alkene, alkyne.
   D) Ketone, alkene, alcohol, alkyne.
   E) Amine, alkene, ether, alkyne.

Ans.: D

6. The number of unique monochloro derivatives of propene is:
   A) 2
   B) 3
   C) 4
   D) 5
   E) 6

Ans.: C

7. List the functional groups found on Prostaglandin E$_1$
8. What is the simplest alkane, i.e., the one with the smallest molecular weight, which possesses primary, secondary and tertiary carbon atoms?
   A) 2-Methylpropane
   B) 2-Methylbutane
   C) 2-Methylpentane
   D) 3-Methylpentane
   E) 2,2-Dimethylbutane

   Ans.: B

9. The compound shown below is the male sex hormone, testosterone.

   ![Prostaglandin E₁]

   In addition to a cycloalkane skeleton, testosterone also contains the following functional groups:
   A) Alkene, ester, tertiary alcohol.
   B) Alkene, ether, secondary alcohol.
   C) Alkene, ketone, secondary alcohol.
   D) Alkyne, ketone, secondary alcohol.
   E) Alkene, ketone, tertiary alcohol.

   Ans.: D

10. Which compound is not an isomer of the others?
Sample Questions CHEM 212
Nicolas Moitessier

11. Which of the following represent a pair of constitutional isomers?
A) \( \text{CH}_3\text{CH}_2\text{CH}_3 \) and \( \text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2 \)
B) \( \text{CH}_2\text{CH}=\text{CH}_2 \) and \( \text{CH}_2\text{CH}_2\text{=CHCH}_3 \)
C) \( \text{Br} \quad \text{Br} \quad \text{H} \quad \text{Br} \)
D) \( \text{Br} \quad \text{H} \quad \text{Br} \quad \text{Br} \)
E) More than one of these

Ans.: D

12. Considering Lewis structures, which of these compounds possesses a single unpaired electron?
A) \( \text{N}_2 \)
B) \( \text{N}_2\text{O} \)
C) \( \text{NO} \)
D) \( \text{N}_2\text{O}_4 \)
E) \( \text{O}_2 \)

Ans.: C
13. Which of the following is a set of constitutional isomers?

\[
\begin{align*}
\text{I} & \quad \text{Br} & \text{II} & \quad \text{CH}_3 \\
\text{III} & \quad \text{CH}_3\text{CHCH}_2\text{Br} & \text{IV} & \quad \text{CH}_3\text{CH}_2\text{Br} \\
\end{align*}
\]

A) I and II \\
B) II and III \\
C) I, II, and III \\
D) II, III, and IV \\
E) I, III, and IV \\

Ans.: E

14. Which of the following structures represent compounds that are constitutional isomers of each other?

\[
\begin{align*}
\text{I} & \quad \text{II} & \quad \text{III} & \quad \text{IV} \\
\end{align*}
\]

A) I and II \\
B) I and III \\
C) I, II, and III \\
D) I, II, III, and IV \\
E) II and III \\

Ans.: C

15. Which functional groups are present in the following compound?

\[
\text{OH} \quad \text{H} \\
\]

A) Alkene, 1º alcohol, ketone \\
B) Alkene, 2º alcohol, aldehyde \\
C) Alkene, 2º alcohol, ketone \\
D) Alkyne, 1º alcohol, aldehyde \\
E) Alkyne, 2º alcohol, ketone \\

Ans.: B

16. How many constitutional isomers are possible with the formula C₄H₁₀O?
17. How many discrete dimethylcyclopropanes are there?

Ans.: 4

18. Which of the following pairs of compounds represent pairs of constitutional isomers?
   A) 2-Methylbutane and pentane
   B) 2-Chlorohexane and 3-chlorohexane
   C) sec-Butyl bromide and tert-butyl bromide
   D) Propyl chloride and isopropyl chloride
   E) All of the above

Ans.: E
Resonance and Hybridization

1. Identify the atomic orbitals in the C-C sigma bond in ethyne
   A) (2sp$^2$, 2sp$^2$)
   B) (2sp$^3$, 2sp$^3$)
   C) (2sp, 2sp)
   D) (2p, 2p)
   E) (2sp, 1s)
   Ans.: C

2. Which of the following contains an sp$^2$-hybridized carbon?
   A) CH$_4$
   B) CH$_3$:
   C) CH$_3$CH$_3$
   D) CH$_3^+$
   E) HC≡CH
   Ans.: D

3. The carbon-carbon bond in the following compound results from the overlap of which orbitals (in the order C$_1$, C$_2$)?

   \[
   \text{H}_3\text{C} - \text{C} = \text{O}
   \]
   A) sp–sp$^2$
   B) sp–sp$^3$
   C) sp$^2$–sp$^2$
   D) sp$^2$–sp$^3$
   E) sp$^3$–sp$^3$
   Ans.: D

4. Which of the following could not be a resonance structure of CH$_3$NO$_2$?
5. Which of the structures below would be trigonal planar (a planar triangle)? (Electrical charges have been deliberately omitted.)

\[ \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \]

A) I
B) II
C) III
D) IV
E) I and IV

Ans.: A

6. Which of the following pairs are NOT resonance structures?
A) 
\[
\begin{align*}
\text{CH}_3\text{O} &= \text{N=O:} \quad \text{and} \quad \text{CH}_3\text{O} &= \text{N-O:} \\
\text{..} &\quad \text{...} \\
\end{align*}
\]
B) 
\[
\begin{align*}
\text{O} &= \text{C=O:} \quad \text{and} \quad \text{O} &= \text{C-O:} \\
\text{..} &\quad \text{...} \\
\end{align*}
\]
C) 
\[
\begin{align*}
\text{CH}_3\text{O} &= \text{N=O:} \quad \text{and} \quad \text{CH}_3\text{N} \\
\text{..} &\quad \text{...} \\
\end{align*}
\]
D) Each of these pairs represents resonance structures.
E) None of these pairs represents resonance structures.

Ans.: C

7. The electron configuration shown below represents:
\[
\begin{align*}
\begin{array}{cccccc}
1s & 2s^2 & 2p^3 & 2s^2 & 2p^3 & 2s^2 \\
\end{array}
\end{align*}
\]
A) the ground state of boron.
B) the sp^3 hybridized state of carbon.
C) the sp^3 hybridized state of nitrogen.
D) the ground state of carbon.
E) an excited state of carbon.

Ans.: C

8. Which principle(s) or rule must be used to determine the correct electronic configuration for carbon in its ground state?
A) Aufbau Principle
B) Hund's Rule
C) Pauli Exclusion Principle
D) (A) and (B) only
E) All three

Ans.: E

9. The electron configuration shown below represents:
\[
\begin{align*}
\begin{array}{cccccc}
1s & 2s^3 & 2s^3 & 2p^3 & 2s^3 & 2p^3 \\
\end{array}
\end{align*}
\]
A) the ground state of boron.
B) the sp^3 hybridized state of carbon.

Ans.: B
C) the sp$^3$ hybridized state of nitrogen.
D) the ground state of carbon.
E) an excited state of carbon.

Ans.: B

10. Which of the following molecules or ions has a nitrogen with a formal charge of -1? (Charges on ions have been omitted.)

A) \( \cdot\cdot\cdot :N-H \)
\( \quad \uparrow \)
\( \quad H \)

B) \( H-N-H \)
\( \quad \uparrow \)
\( \quad H \)

C) \( H-N-CH_3 \)
\( \quad \uparrow \)
\( \quad H \)

D) \( \cdot\cdot\cdot CH_3-N-CH_3 \)
\( \quad \uparrow \)
\( \quad H \)

E) \( CH_3C\equiv N:\)

Ans.: A

11. VSEPR theory predicts an identical shape for all of the following, except:

A) \( NH_3 \)
B) \( H_3O^+ \)
C) \( BH_3 \)
D) \( CH_3^- \)
E) All have the same geometry.

Ans.: C

12. Which of the following would have a trigonal planar (or triangular) structure?

\[ \begin{array}{cccc}
\cdot & + & + & + \\
:\text{CH}_3 & \text{CH}_3 & :\text{NH}_3 & \text{BF}_3 & :\text{OH}_3 \\
\quad & \quad & \quad & \quad & \quad \\
I & II & III & IV & V \\
\end{array} \]

A) I, II, and IV
B) II and IV
C) IV
D) II, IV, and V
E) All of these

Ans.: B
13. The C–O–C bond angle in diethyl ether is predicted to be approximately:
   A) 90º
   B) 105º
   C) 110º
   D) 120º
   E) 180º

   Ans.: B

14. The hybridization state of the carbon of a methyl radical is:
   A) sp
   B) sp²
   C) sp³
   D) sp⁴
   E) p³

   Ans.: B

15. Listed below are electron dot formulas for several simple molecules and ions. All valence electrons are shown; however, electrical charges have been omitted deliberately. Which of the structures actually bear(s) a positive charge?

   Ans.: IV and V

16. In which of the following would you expect the central atom to be sp³ hybridized (or approximately sp³ hybridized)?
   A) BH₄⁻
   B) NH₄⁺
   C) CCl₄
   D) CH₃⁻
   E) All of these

   Ans.: E

17. According to molecular orbital theory, which molecule could not exist?
A) $\text{H}_2$
B) $\text{He}_2$
C) $\text{Li}_2$
D) $\text{F}_2$
E) $\text{N}_2$

Ans.: B
Acid-Base Reactions

1. The amide ion, NH$_2^-$, is a base which can be used only in which of the solvents shown below:
   A) CH$_3$OH
   B) CH$_3$CH$_2$OH
   C) H$_2$O
   D) D$_2$O
   E) Liquid NH$_3$

   Ans.: E

2. Which sequence is the best one to use to prepare CH$_3$C≡CD?
   A) CH$_3$C≡CH $\xrightarrow{\text{NaH}}$ D$_2$O
   B) CH$_3$C≡CH $\xrightarrow{\text{NaOH}}$ D$_2$O
   C) CH$_3$C≡CH $\xrightarrow{\text{CH$_3$ONa}}$ D$_2$O
   D) CH$_3$C≡CH $\xrightarrow{\text{D}_{2}H}$
   E) None of these will be successful.

   Ans.: A

3. Which is an incorrect statement?
   A) RSH compounds are stronger acids than ROH compounds.
   B) PH$_3$ is a weaker base than NH$_3$.
   C) NH$_2^-$ is a stronger base than OH$^-$.
   D) OH$^-$ is a stronger base than OR$^-$.
   E) H$^-$ is a stronger base than OR$^-$.

   Ans.: D

4. The basic species are arranged in decreasing order of basicity in the sequence:
   A) F$^-$ > OCH$_3^-$ > NH$_2^-$ > CH$_3$CH$_2^-$
   B) OCH$_3^-$ > CH$_3$CH$_2^-$ > NH$_2^-$ > F$^-$
   C) CH$_3$CH$_2^-$ > NH$_2^-$ > OCH$_3^-$ > F$^-$
   D) NH$_2^-$ > CH$_3$CH$_2^-$ > F$^-$ > OCH$_3^-$
   E) NH$_2^-$ > OCH$_3^-$ > CH$_3$CH$_2^-$ > F$^-$

   Ans.: C
5. What prediction can be made of the relative strengths of the conjugate bases of: \( \text{H}_2\text{S}, \text{HCl}, \text{SiH}_4, \text{PH}_3 \)?
   A) \( \text{PH}_2^- > \text{SiH}_3^- > \text{HS}^- > \text{Cl}^- \)
   B) \( \text{SiH}_3^- > \text{PH}_2^- > \text{HS}^- > \text{Cl}^- \)
   C) \( \text{Cl}^- > \text{HS}^- > \text{PH}_2^- > \text{SiH}_3^- \)
   D) \( \text{HS}^- > \text{Cl}^- > \text{SiH}_3^- > \text{PH}_2^- \)
   E) \( \text{Cl}^- > \text{PH}_2^- > \text{SiH}_3^- > \text{HS}^- \)
   Ans.: B

6. Which of the following correctly lists the compounds in order of decreasing acidity?
   A) \( \text{H}_2\text{O} > \text{HC}=\text{CH} > \text{NH}_3 > \text{CH}_3\text{CH}_3 \)
   B) \( \text{HC}=\text{CH} > \text{H}_2\text{O} > \text{NH}_3 > \text{CH}_3\text{CH}_3 \)
   C) \( \text{CH}_3\text{CH}_3 > \text{HC}=\text{CH} > \text{NH}_3 > \text{H}_2\text{O} \)
   D) \( \text{CH}_3\text{CH}_3 > \text{HC}=\text{CH} > \text{H}_2\text{O} > \text{NH}_3 \)
   E) \( \text{H}_2\text{O} > \text{NH}_3 > \text{HC}=\text{CH} > \text{CH}_3\text{CH}_3 \)
   Ans.: A

7. A group of acids arranged in order of decreasing acidity is:
   \( \text{HNO}_3 > \text{CH}_3\text{COOH} > \text{C}_6\text{H}_5\text{OH} > \text{H}_2\text{O} > \text{HC}=\text{CH} \)
What is the arrangement of the conjugate bases of these compounds in decreasing order of basicity?
   A) \( \text{NO}_3^- > \text{CH}_3\text{COO}^- > \text{C}_6\text{H}_5\text{O}^- > \text{OH}^- > \text{HC}=\text{C}^- \)
   B) \( \text{CH}_3\text{COO}^- > \text{C}_6\text{H}_5\text{O}^- > \text{NO}_3^- > \text{OH}^- > \text{HC}=\text{C}^- \)
   C) \( \text{C}_6\text{H}_5\text{O}^- > \text{NO}_3^- > \text{HC}=\text{C}^- > \text{OH}^- > \text{CH}_3\text{COO}^- \)
   D) \( \text{HC}=\text{C}^- > \text{OH}^- > \text{C}_6\text{H}_5\text{O}^- > \text{CH}_3\text{COO}^- > \text{NO}_3^- \)
   E) No prediction of relative base strength is possible.
   Ans.: D

8. Which combination of substances below does not constitute a Lewis acid-Lewis base reaction?
   A) \( \text{PH}_3 + \text{H}^+ \)
   B) \( \text{Ag}^+ + \text{NH}_3/\text{H}_2\text{O} \)
   C) \( \text{BF}_3 + \text{NH}_3 \)
   D) \( \text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{AlCl}_3 \)
   E) \( \text{OH}^- + \text{NH}_3/\text{H}_2\text{O} \)
   Ans.: E
9. Give definitions of a Lewis acid and a Lewis base.

10. For the equilibrium shown below, the two substances which both are acids are:

\[
\text{CH}_3\text{NH}_3^+ + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{NH}_2 + \text{H}_3\text{O}^+
\]

A) \( \text{H}_2\text{O} \) and \( \text{H}_3\text{O}^+ \)
B) \( \text{CH}_3\text{NH}_3^+ \) and \( \text{H}_2\text{O} \)
C) \( \text{CH}_3\text{NH}_3^+ \) and \( \text{CH}_3\text{NH}_2 \)
D) \( \text{CH}_3\text{NH}_3^+ \) and \( \text{H}_3\text{O}^- \)
E) \( \text{CH}_3\text{NH}_2 \) and \( \text{H}_2\text{O} \)

Ans.: D

11. Which of the following is not a Lewis base?
   A) \( \text{NH}_3 \)
   B) \( \text{H}^- \)
   C) \( \text{BF}_3 \)
   D) \( \text{H}_2\text{O} \)
   E) \( \text{H}_3\text{C}^- \)

Ans.: C

12. Which of the following is not a Bronsted-Lowry acid?
   A) \( \text{H}_2\text{O} \)
   B) \( (\text{CH}_3)_3\text{N} \)
   C) \( \text{NH}_4^+ \)
   D) \( \text{CH}_3\text{CO}_2\text{H} \)
   E) \( \text{HC}≡\text{CH} \)

Ans.: B

13. Which of the acids below would have the strongest conjugate base?
   A) \( \text{CH}_3\text{CH}_2\text{OH} \) \( \text{pK}_a = 18 \)
   B) \( \text{CH}_3\text{CO}_2\text{H} \) \( \text{pK}_a = 4.75 \)
   C) \( \text{ClCH}_2\text{CO}_2\text{H} \) \( \text{pK}_a = 2.81 \)
   D) \( \text{Cl}_2\text{CHCO}_2\text{H} \) \( \text{pK}_a = 1.29 \)
   E) \( \text{Cl}_3\text{CCO}_2\text{H} \) \( \text{pK}_a = 0.66 \)

Ans.: A
14. Which combination of reagents is the least effective in generating sodium ethoxide, CH₃CH₂ONa?
   A) CH₃CH₂OH + NaH
   B) CH₃CH₂OH + NaNH₂
   C) CH₃CH₂OH + NaOH
   D) CH₃CH₂OH + CH₃Li
   E) CH₃CH₂OH + HC≡CNa

   Ans.: C

15. In the reaction, Na⁺NH₂⁻ + CH₃OH → CH₃O⁻Na⁺ + NH₃, the stronger base is:
   A) NaNH₂
   B) CH₃OH
   C) CH₃ONa
   D) NH₃
   E) This is not an acid-base reaction.

   Ans.: A

16. Select the strongest base.
   A) OH⁻
   B) RC≡C⁻
   C) NH₂⁻
   D) CH₂=CH⁻
   E) CH₃CH₂⁻

   Ans.: E

17. The basic species are arranged in decreasing order of basicity in the sequence:
   A) OCH₃⁻ > CH₃CH₂⁻ > NH₂⁻ > F⁻
   B) CH₃CH₂⁻ > NH₂⁻ > OCH₃⁻ > F⁻
   C) F⁻ > OCH₃⁻ > NH₂⁻ > CH₃CH₂⁻
   D) NH₂⁻ > CH₃CH₂⁻ > F⁻ > OCH₃⁻
   E) NH₂⁻ > OCH₃⁻ > CH₃CH₂⁻ > F⁻

   Ans.: B

18. For the simple hydrides, MHₙ, pKₐ values decrease in the order:
   A) CH₄ > NH₃ > H₂O > H₂S > HBr
   B) HBr > H₂S > H₂O > NH₃ > CH₄
C) HBr > H₂O > NH₃ > H₂S > CH₄
D) NH₃ > H₂S > CH₄ > H₂O > HBr
E) H₂S > H₂O > HBr > NH₃ > CH₄

Ans.: A

19. When proton transfer reactions reach equilibrium, there have been formed:
   A) the weaker acid and the weaker base.
   B) the weaker acid and the stronger base.
   C) the stronger acid and the weaker base.
   D) the stronger acid and the stronger base.
   E) All proton transfers go to completion; they are not equilibrium processes.

Ans.: A
Nomenclature

1. The correct IUPAC name for the following compound is:

![Chemical structure]

A) 1-Hydroxy-3-sec-butylcyclopentane
B) 3-sec-Butyl-1-cyclopentanol
C) 1-sec-Butyl-3-cyclopentanol
D) 4-sec-Butyl-1-cyclopentanol
E) 3-Isobutyl-1-cyclopentanol

Ans.: B

2. The correct IUPAC name for the following compound is:

![Chemical structure]

A) 2-Bromo-4-chloro-4-isopropylpentane
B) 4-Bromo-2-chloro-2-isopropylpentane
C) 5-Bromo-3-chloro-2,3-dimethylhexane
D) 2-Bromo-4-chloro-4,5-dimethylhexane
E) 2-(2-Bromopropyl)-2-chloro-3-methylbutane

Ans.: C

3. The correct IUPAC name for the following compound is:

![Chemical structure]

A) 3-Hydroxymethylheptane
B) 3-Hydroxymethylhexane
C) 3-Methoxyheptane
D) 2-Ethyl-1-hexanol
E) 2-Ethyl-1-heptanol

Ans.: D
4. A correct IUPAC name for the following compound is:

\[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{CHCHCH}_3 \\
\quad \quad \quad | \\
\quad \quad \quad \text{CH}_3 \\
\text{CH}_2\text{CH}_2\text{CH}_3
\end{array}
\]

A) 2,5-Dimethyl-3-propylheptane  
B) 3,6-Dimethyl-5-propylheptane  
C) 6-Methyl-4-(1-methylethyl)octane  
D) 2-Methyl-3-(2-methylbutyl)hexane  
E) 3-Methyl-5-(1-methylethyl)octane

Ans.: E
Alkane, conformational analysis

1. Select the systematic name for

A) cis-1,3-Dichlorocyclopentane
B) trans-1,4-Dichlorocyclopentane
C) cis-1,2-Dichlorocyclopentane
D) trans-1,3-Dichlorocyclopentane
E) 1,1-Dichlorocyclopentane

Ans.: D

2. trans-1,2-Dibromocyclohexane is represented by structure(s):

Ans.: II and III

3. Which conformation represents the most stable conformation of cis-1-tert-butyl-4-methylcyclohexane?

Ans.: II

4. Which of the compounds listed below would you expect to have the highest boiling point? (They all have approximately the same molecular weight.)
Sample Questions
Nicolas Moitessier

A) CH₃CH₂CH₂CH₂CH₃
B) CH₃CH₂CH₂CH₂OH
C) CH₃CH₂CH₂OCH₃
D) CH₃CH₂CH₂Cl
E) CH₃CH₂OCH₂CH₃

Ans.: B

5. Which compound would have the lowest solubility in water?
A) Diethyl ether
B) Methyl propyl ether
C) 1-Butanol
D) 2-Butanol
E) Pentane

Ans.: E

6. Which one of the following conformation of butane is the least stable

![Conformations of Butane]

Ans.: II

7. The most stable conformation of cis-1-tert-butyl-2-methylcyclohexane is the one in which:
A) the tert-butyl group is axial and the methyl group is equatorial.
B) the methyl group is axial and the tert-butyl group is equatorial.
C) both groups are axial.
D) both groups are equatorial.
E) the twist boat conformation is adopted.

Ans.: B

8. Which of these C₁₀H₁₈ isomers is predicted to be the most stable?
Ans. V


## Stereochemistry

1. Chiral molecules are represented by:

   \[
   \begin{align*}
   \text{A} & : C_6H_5 CH_3 Cl \\
   \text{B} & : C_6H_5 Cl CH_3 \\
   \text{C} & : C_6H_5 H Cl \\
   \text{D} & : C_6H_5 Cl H \\
   \text{E} & : C_6H_5 H H \\
   \end{align*}
   \]

   Ans.: C and D

2. Which compound does NOT possess a plane of symmetry?

   \[
   \begin{align*}
   \text{I} & : \text{CH}_3 \text{CH}_3 \text{H} \text{H} \\
   \text{II} & : \text{Br} \text{H} \text{H} \text{Cl} \\
   \text{III} & : \text{HO} \text{OH} \text{H} \text{H} \\
   \text{IV} & : \text{F} \text{H} \text{H} \text{F} \\
   \text{V} & : \text{HO} \text{H} \text{H} \text{OH} \\
   \end{align*}
   \]

   Ans.: V

3. Which structure represents (S)-1-chloro-1-fluoroethane?

   \[
   \begin{align*}
   \text{A} & : \text{Cl} \text{CH}_3 \text{H} \\
   \text{B} & : \text{H} \text{F} \text{Cl} \text{CH}_3 \\
   \text{C} & : \text{H}_3 \text{C} \text{F} \text{Cl} \\
   \end{align*}
   \]

   Ans.: I and III

4. The Cahn-Ingold-Prelog stereochemical designations used for the following compound are:
A) 2R,4S
B) 2S,4R
C) 2R,4R
D) 2S,4S
E) The R,S terminology doesn't apply in this case.

Ans.: C

5. Which one of the following can exist in optically active forms?
A) cis-1,3-Dichlorocyclohexane
B) trans-1,3-Dichlorocyclohexane
C) cis-1,4-Dichlorocyclohexane
D) trans-1,4-Dichlorocyclohexane
E) cis-1,2-Dichlorocyclohexane

Ans.: B

6. What can be said with certainty if a compound has $\left[\alpha\right]_D^{25} = -9.25^\circ$?
A) The compound has the (S) configuration.
B) The compound has the (R) configuration.
C) The compound is not a meso form.
D) The compound possesses only one stereogenic center.
E) The compound has an optical purity of less than 100%.

Ans.: C

7. CH$_3$CHBrCHBrCHBrCH$_3$ is the generalized representation of what number of stereoisomers?

Ans.: 4

8. Which of the following compounds B, C D or E is the enantiomer of A?

Ans.: A does not have a non-superposable enantiomer

9. The following two molecules are:
A) constitutional isomers.
B) enantiomers.
C) diastereomers.
D) identical.
E) None of these.

Ans.: B

10. The following two molecules are:

A) constitutional isomers.
B) enantiomers.
C) diastereomers.
D) identical.
E) None of these.

Ans.: D

11. The following two molecules are:

A) constitutional isomers.
B) enantiomers.
C) diastereomers.
D) identical.
E) None of these.

Ans.: A

12. The following two molecules are:
13. Which molecule is achiral?

![Molecules](image)

A) constitutional isomers.
B) enantiomers.
C) diastereomers.
D) identical.
E) None of these.

Ans.: C

14. Which of the following is a meso compounds?

![Molecules](image)

Ans.: A

15. Which compound does NOT possess a plane of symmetry?
16. Which of the following represent (R)-2-butanol?

\[ \text{A)} \quad \begin{array}{c} \text{H}_3\text{C} \\
\text{CH}_2\text{CH}_3 \\
\text{OH} \\
\end{array} \quad \text{B)} \quad \begin{array}{c} \text{H}_3\text{C} \\
\text{CH}_2\text{CH}_3 \\
\text{OH} \\
\end{array} \quad \text{C)} \quad \begin{array}{c} \text{H}_3\text{C} \\
\text{OH} \\
\text{CH}_2\text{CH}_3 \\
\end{array} \quad \text{D)} \quad \begin{array}{c} \text{H}_3\text{C} \\
\text{CH}_2\text{CH}_3 \\
\text{OH} \\
\end{array} \quad \text{E)} \quad \begin{array}{c} \text{H}_3\text{C} \\
\text{CH}_2\text{CH}_3 \\
\text{OH} \\
\end{array} \]

Ans.: A, D and E

17. What is the percent composition of a mixture of (S)-(+)2-butanol, \([\alpha]_D^{25} = +13.52^\circ\), and (R)(-)-2-butanol, \([\alpha]_D^{25} = -13.52^\circ\), with a specific rotation \([\alpha]_D^{25} = +6.76^\circ\)?

Ans.: 25%(R) 75%(S)

18. Which one of the following can exist in optically active forms?

A) \text{cis-1,3-Dichlorocyclohexane}
B) \text{trans-1,3-Dichlorocyclohexane}
C) \text{cis-1,4-Dichlorocyclohexane}
D) \text{trans-1,4-Dichlorocyclohexane}
E) \text{cis-1,2-Dichlorocyclohexane}

Ans: B

19. What can be said with certainty if a compound has \([\alpha]_D^{25} = -9.25^\circ\) ?

A) The compound has the (S) configuration.
B) The compound has the (R) configuration.
C) The compound is not a \textit{meso} form.
D) The compound possesses only one stereogenic center.
E) The compound has an optical purity of less than 100%.
20. Which of the following is true about any (R)-enantiomer?
A) It is dextrorotatory.
B) It is levorotatory.
C) It is an equal mixture of + and -.
D) It is the mirror image of the (S)-enantiomer.
E) (R) indicates a racemic mixture.

Ans.: D

21. When using the Cahn-Ingold-Prelog rules for prioritizing groups on a stereogenic carbon, priority is first assigned on the basis of ______________________

Ans.: atomic number

20. Give definitions of constitutional isomers and stereoisomers

21. Draw the most stable conformation of trans-1-methyl-4-tert-butyl-cyclohexane

Ans.:
Nucleophilic Substitution

1. The rate equation for an S_N1 reaction of an alkyl bromide (R-Br) with I^- ion would be:
   A) Rate = k [RBr]
   B) Rate = k [I^-]
   C) Rate = k [RBr][I^-]
   D) Rate = k [RBr]^2[I^-]
   E) Rate = k [RBr][I^-]^2

   Ans.: A

2. What product(s) would you expect to obtain from the following S_N2 reaction?

   \[ \begin{align*}
   &\text{H} &\text{H} \\
   &\text{CH}_3 &\text{Br} \\
   &\text{CH}_3 &\text{OCH}_3
   
   \text{CH}_3
   &\text{OH} \rightarrow \text{CH}_2\text{OH} \\
   &\text{H} &\text{CH}_3 \\
   &\text{OCH}_3 &\text{Br}
   \end{align*} \]

   A) I
   B) II
   C) An equimolar mixture of I and II.
   D) III
   E) None of these

   Ans.: B

3. What would be the major product of the following reaction?

   \[ \begin{align*}
   \text{NH}_2
   &\text{H} &\text{CH}_3 \\
   &\text{H} &\text{CH}_3
   &\text{CH}_2\text{Cl} \\
   &\text{H} &\text{CH}_3
   \end{align*} \] + \[ \text{OH}^- \rightarrow \text{S}_\text{N}2 \]

   \[ \begin{align*}
   &\text{CH}_3 &\text{H} &\text{CH}_2\text{OH} \\
   &\text{I} \\
   &\text{H} &\text{CH}_3 &\text{CH}_2\text{OH} \\
   &\text{II} \\
   &\text{CH}_3 &\text{H} &\text{CH}_2\text{Cl} \\
   &\text{III} \\
   &\text{H} &\text{CH}_3 &\text{CH}_2\text{Cl} \\
   &\text{IV}
   \end{align*} \]
4. When 0.10 mol of ICH₂CH₂CH₂CH₃Cl reacts with 0.10 mol of NaOCH₃ in CH₃OH at 40°C, the major product is:
A) CH₃OCH₂CH₂CH₂CH₃Cl
B) CH₃OCH₂CH₂CH₂CH₂I
C) CH₃OCH₂CH₂CH₂CH₂OCH₃
D) CH₂=CHCH₂CH₂Cl
E) CH₂=CHCH₂CH₂I
Ans.: A

5. Which reaction would be expected to occur most slowly?
A) CH₃CH₂F + CN⁻
B) CH₃CH₂Cl + CN⁻
C) CH₃CH₂Br + CN⁻
D) CH₃CH₂I + CN⁻
E) CH₃CH₂OH + CN⁻
Ans.: E

6. Which of the following statements is (are) true of S_N1 reactions of alkyl halides in general?
A) The rate of an S_N1 reaction depends on the concentration of the alkyl halide.
B) The rate of an S_N1 reaction depends on the concentration of the nucleophile.
C) S_N1 reactions of alkyl halides are favored by polar solvents.
D) Answers A) and C) only are true.
E) Answers A), B) and C) are true.
Ans.: D

7. Which of the following statements is (are) true of an S_N2 reaction of (R)-2-bromobutane with hydroxide ion?
A) Doubling the hydroxide ion concentration would double the rate of the reaction. (Assume that all other experimental conditions are unchanged.)
B) The reaction would occur with inversion of configuration.
C) Doubling the concentration of (R)-2-bromobutane would double the rate of the reaction. (Assume that all other experimental conditions are unchanged.)
D) All of the above
E) None of the above
Ans.: D
8. Which of the following is not a good leaving group?
A) OH⁻
B) Cl⁻
C) Br⁻
D) RSO₃⁻
E) ROSO₃⁻
Ans.: A

9. Identify the leaving group in the following reaction.
\[ \text{C}_6\text{H}_5\text{S}^+ \text{Na}^+ + \text{CH}_3\text{CH}_2\text{I} \rightarrow \text{C}_6\text{H}_5\text{SCH}_2\text{CH}_3 + \text{Na}^+ + \text{I}^- \]
Ans.: I⁻

10. Which is a true statement concerning the transition state of the rate-determining step of an S_N1 reaction?
A) Structurally, it closely resembles the carbocation intermediate.
B) Both covalent bond-breaking and bond-making are occurring.
C) Formation of the transition state is an exothermic reaction.
D) Necessarily, the transition state has zero charge overall.
E) More than one of the above.
Ans.: A

11. Consider the substitution reaction that takes place when (R)-3-bromo-3-methylhexane is treated with methanol. Which of the following would be true?
A) The reaction would take place only with inversion of configuration at the stereogenic center.
B) The reaction would take place only with retention of configuration at the stereogenic center.
C) The reaction would take place with racemization.
D) No reaction would take place. The alkyl halide does not possess a stereogenic center.
E) 
Ans.: C

12. Which alkyl halide would be the most reactive in an S_N2 reaction?
13. S_N2 reactions of the type, Nu^- + RL → Nu-R + L^-, are favored:
A) when tertiary substrates are used.
B) by using a high concentration of the nucleophile.
C) by using a solvent of high polarity.
D) by the use of weak nucleophiles.
E) by none of the above.

Ans. B

14. For the nucleophilic substitution reaction
Br^- + CH_3CH_2CH_2CH_2CH_2OH →
to be successful, it is necessary that:
A) the reaction be carried out at high temperature.
B) a large excess of Br^- be used.
C) the reaction be carried out at low pH.
D) a polar aprotic solvent be used.
E) Under none of these conditions can this synthesis be accomplished.

Ans.: C

15. Select the strongest nucleophile for an S_N2 reaction.
A) H_2O
B) ROH
C) RCO_2^-
D) OH^-
E) RO^-

Ans.: E
16. Which alkyl halide would you expect to undergo $S_N_1$ hydrolysis most rapidly?
A) $(CH_3)_3Cl$
B) $(CH_3)_3CBr$
C) $(CH_3)_3CCl$
D) $(CH_3)_3CF$
E) They would all react at the same rate.

Ans.: A

17. Which of the following pentyl halides would you expect to give the highest yield of substitution product under conditions for a bimolecular reaction with ethoxide ion?
A) $CH_3CH_2CH_2CH_2CH_2Br$
B) $CH_3CH_2CH_2CH_2Br$
C) $CH_3CH_2CH_2CH_2Br$
D) $CH_3CH_2CH_2CH_2Br$
E) $CH_3CH_2CH_2CH_2Br$

Ans.: A

18. Which $S_N_2$ reaction will occur most rapidly in a mixture of water and ethanol?
A) $I^- + CH_3CH_2Br \rightarrow CH_3CH_2I + Br^-$
B) $I^- + CH_3CH_2Cl \rightarrow CH_3CH_2I + Cl^-$
C) $I^- + CH_3CH_2F \rightarrow CH_3CH_2I + F^-$
D) $Br^- + CH_3CH_2Cl \rightarrow CH_3CH_2Br + Cl^-$
E) $Br^- + CH_3CH_2F \rightarrow CH_3CH_2Br + F^-$

Ans.: A

19. Which $S_N_2$ reaction would be expected to occur most rapidly?
A) $CH_3CH_2F + CN^-$
B) $CH_3CH_2Cl + CN^-$
C) $CH_3CH_2Br + CN^-$
D) $CH_3CH_2I + CN^-$
E) CH₃CH₂OH + CN⁻

Ans.: D

20. Which nucleophilic substitution reaction is not likely to occur?
   A) I⁻ + CH₃CH₂–Cl → CH₃CH₂–I + Cl⁻
   B) I⁻ + CH₃CH₂–Br → CH₃CH₂–I + Br⁻
   C) I⁻ + CH₃CH₂–OH → CH₃CH₂–I + OH⁻
   D) CH₃O⁻ + CH₃CH₂–Br → CH₃CH₂–OCH₃ + Br⁻
   E) OH⁻ + CH₃CH₂–Cl → CH₃CH₂–OH + Cl⁻

Ans.: C

21. Which of these ethers is least likely to undergo significant cleavage by hot aqueous H₂SO₄?

\[
\begin{array}{ccc}
\text{CH₃OCH₃} & \text{CH₃OCH(CH₃)₂} & (\text{CH₃})₂\text{CHOCH(CH₃)₂} \\
\text{I} & \text{II} & \text{III} \\
(\text{CH₃})₃\text{COC(CH₃)₃} & \text{IV} & \text{V}
\end{array}
\]

Ans.: I

22. Which alcohol would initially produce the most stable carbocation when treated with concentrated H₂SO₄?

   A) \[
   \begin{array}{c}
   \text{CH₃} \\
   \text{CH₃CCH₂CH₃} \\
   \text{OH}
   \end{array}
   \]

   B) \[
   \begin{array}{c}
   \text{CH₃} \\
   \text{CH₃CHCH₂CH₃} \\
   \text{OH}
   \end{array}
   \]

   C) \[
   \begin{array}{c}
   \text{CH₃} \\
   \text{CH₃CHCH₂CH₂OH}
   \end{array}
   \]

   D) \[
   \begin{array}{c}
   \text{CH₃} \\
   \text{HOCH₂CHCH₂CH₃}
   \end{array}
   \]

   E) \[
   \begin{array}{c}
   \text{CH₂OH} \\
   \text{CH₃CHCH₂CH₃}
   \end{array}
   \]

Ans.: A
Alkenes and Elimination Reaction

1. Consider the following:

\[
\begin{align*}
\text{I} & : \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_3 \\
\text{II} & : \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2 \\
\text{III} & : \text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \\
\text{IV} & : \text{CH}_2=\text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3
\end{align*}
\]

Which structures can exist as cis-trans isomers?

A) I and II  
B) I and III  
C) I and IV  
D) II and III  
E) I alone

Ans.: B

2. Treating (CH\textsubscript{3})\textsubscript{3}C-Cl with a mixture of H\textsubscript{2}O and CH\textsubscript{3}OH at room temperature would yield:

A) CH\textsubscript{2}=C(CH\textsubscript{3})\textsubscript{2}  
B) (CH\textsubscript{3})\textsubscript{3}COH  
C) CH\textsubscript{3}(CH\textsubscript{3})\textsubscript{2}COCH\textsubscript{3}  
D) All of these  
E) None of these

Ans.: D

3. Which would be the major product of the following reaction?

\[
\begin{align*}
&\text{CH}_3 \quad \text{H} \\
&\text{H} \quad \text{Cl} \\
\xrightarrow[55^\circ\text{C}]{\text{(CH}_3\text{)}_2\text{CO}^-} & \text{?} \\
\end{align*}
\]

\[
\begin{align*}
\text{I} & : \text{CH}_3 \quad \text{OC(CH}_3\text{)}_3 \\
\text{II} & : \text{CH}_3 \quad \text{HC(CH}_3\text{)}_3 \\
\text{III} & : \text{CH}_3 \\
\text{IV} & : \text{CH}_3
\end{align*}
\]

Ans.: III
4. Your task is to convert 2-chloropentane into 1-pentene. Which reagents would you choose?
A) NaOH/H₂O
B) KOH/CH₃OH
C) CH₃ONa/CH₃OH
D) CH₃CH₂ONa/CH₃CH₂OH
E) (CH₃)₃COK/(CH₃)₃COH

Ans.: E

5. Elimination reactions are favored over nucleophilic substitution reactions:
A) at high temperatures.
B) when tert-butoxide ion is used.
C) when 3° alkyl halides are used as substrates.
D) when nucleophiles are used which are strong bases and the substrate is a 2° alkyl halide.
E) in all of these cases.

Ans.: E

6. Which product(s) would be produced by acid-catalyzed dehydration of the following alcohol?

\[
\begin{align*}
\text{CH}_3 & \quad \text{HA, heat} \quad \rightarrow \\
\text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_3 & \quad (-\text{H}_2\text{O})
\end{align*}
\]

A) \( \text{CH}_2 \)
\( \text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_3 \)
B) \( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2=\text{CCH}_2\text{CH}_2\text{CH}_3 \) and \( \text{CH}_3\text{C}=\text{CHCH}_2\text{CH}_3 \)
C) \( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_3\text{CHCH}=\text{CHCH}_3 \) and \( \text{CH}_3\text{CHCH}_2\text{CH}=\text{CH}_2 \)
D) \( \text{CH}_3 \)
\( \text{CH}_3\text{CHCH}_2\text{CH}=\text{CH}_2 \)
E) \( \text{CH}_3 \quad \text{CH}_3 \)
\( \text{CH}_3\text{CH}_2\text{CH}_2\text{C}=\text{O}–\text{CCH}_2\text{CH}_2\text{CH}_3 \)
\( \text{CH}_3 \quad \text{CH}_3 \)

Ans.: B
7. Treating \((\text{CH}_3)_3\text{C-Cl}\) with a mixture of \(\text{H}_2\text{O}\) and \(\text{CH}_3\text{OH}\) at room temperature would yield:
A) \(\text{CH}_2=\text{C(\text{CH}_3)}_2\)
B) \((\text{CH}_3)_3\text{COH}\)
C) \((\text{CH}_3)_3\text{COCH}_3\)
D) All of these
E) None of these

Ans.: D

8. Which would be formed in the following reaction?

\[
\begin{align*}
\text{CH}_3 \quad \text{B} & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{H} & \quad \text{H} \\
\text{OCH}_3 & \quad \text{OCH}_3
\end{align*}
\]

Ans.: All of the above

9. The major product(s) of the following reaction is(are):

\[
\begin{align*}
\text{H} & \quad \text{I} & \quad \text{II} & \quad \text{III} & \quad \text{IV} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{Cl}
\end{align*}
\]

Ans.: I

10. You want to synthesize 2-methyl-1-butene from 2-chloro-2-methylbutane. Which reagent would you use?
A) NaOH/H₂O  
B) KOH/H₂O  
C) (CH₃)₃CO/(CH₃)₃COH  
D) CH₃CH₂ONa/CH₃CH₂OH  
E) CH₃ONa/CH₃OH  

Ans.: C

11. Reaction of sodium ethoxide with 2-bromopentane at 50°C yields primarily:
A) CH₃CH₂CH₂CH=CH₂  
B) CH₃CH₂CH=CHCH₃  
C) CH₃CH₂CH₂CH₂CH₃  
D) CH₃CH₂CH₂CH₂CH₂OH  
E) CH₃CH₂CH₂CH₂CH₂OCH₂CH₃  

Ans.: B

12. Which compound listed below would you expect to be the major product of this reaction?

\[
\begin{align*}
\text{CH₃} & \quad \text{CH₃CH₂CEr} & \quad \text{KOH} & \quad \text{ethanol} & \quad \text{reflux} \\
\text{CH₃} & \quad \text{CH₃CH₂COH} & & & \\
\text{CH₃} & \quad \text{CH₃CH₂C=O-CH₂CH₃} & & & \\
\text{CH₃} & \quad \text{CH₃CH₂C=CH₂} & & & \\
\end{align*}
\]

A) CH₃  
B) CH₃CH₂COH  
C) CH₃CH₂C=CH₂  
D) CH₃CH₂C=CCH₃  
E) CH₂=CHCHCH₃  

Ans.: D

13. Predict the major product.
14. Which compound listed below would you expect to be the major product of this reaction?

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CBr} & \quad + \quad \text{KOH} \quad \xrightarrow{\text{ethanol, reflux}} \quad ? \\
\text{CH}_3 & \quad \text{CH}_3
\end{align*}
\]

A) \quad \begin{align*}
\text{CH}_3 \\
\text{CH}_3\text{CH}_2\text{COH} \\
\text{CH}_3
\end{align*}

B) \quad \begin{align*}
\text{CH}_3\text{CH}_2\text{C}:=\text{O}\text{C}:=\text{CH}_2\text{CH}_3 \\
\text{CH}_3
\end{align*}

C) \quad \begin{align*}
\text{CH}_3\text{CH}_2\text{C}:=\text{CH}_2 \\
\text{CH}_3
\end{align*}

D) \quad \begin{align*}
\text{CH}_3\text{CH}=:\text{CCH}_3 \\
\text{CH}_3
\end{align*}

E) \quad \begin{align*}
\text{CH}_2=:\text{CHCHCH}_3 \\
\text{CH}_3
\end{align*}

Ans. D

15. Which product(s) would be produced by acid-catalyzed dehydration of the following alcohol?
16. What is the major product of the following reaction?

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3\text{CCH}_2\text{CCH}_2\text{CH}_3 & + \text{C}_2\text{H}_5\text{ONa} \quad \overset{\text{C}_2\text{H}_5\text{OH}}{\longrightarrow} \quad ?
\end{align*}
\]

A) \[\text{CH}_2=\text{CH}=\text{CH}=\text{CH}_3\]

B) \[\text{CH}_3 \quad \text{CH}_3 \]

C) \[\text{CH}_3\text{CH}2=\text{C}=\text{C}=\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3\]

D) \[\text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3\text{CH}2=\text{C}=\text{C}=\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3\]

E) \[\text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3\text{CH}2=\text{C}=\text{C}=\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3\]

Ans.: C

17. Which product (or products) would be formed in appreciable amount(s) when trans-1-bromo-
2-methylcyclohexane undergoes dehydrohalogenation upon treatment with sodium ethoxide in ethanol?

Ans.: II

18. What is the major product of the reaction,

\[
\begin{align*}
\text{CH}_3 & \quad \text{Br} \\
\nearrow & \quad \downarrow \\
\text{CH}_3 & \quad \text{C} \quad \text{CH} \quad \text{CH}_3 & \quad (\text{CH}_3)_3\text{CO}^- \\
\text{CH}_3 & \quad & \quad (\text{CH}_3)_3\text{COH}
\end{align*}
\]

A) \((\text{CH}_3)_2\text{C}=\text{C}(\text{CH}_3)\)
B) \((\text{CH}_3)_3\text{C}–\text{CH}=\text{CH}_2\)
C) \((\text{CH}_3)_2\text{C}=\text{CHCH}_3\)
D) \((\text{CH}_3)_2\text{C}=\text{CHCH}_2\text{CH}_3\)
E) None of these

Ans.: B

19. What would be the major product of the following reaction?

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} \\
\downarrow & \quad \downarrow \\
\text{CH}_3 & \quad \text{CH}_2–\text{C}–\text{Cl} & \quad \text{CH}_3\text{ONa} & \quad \text{CH}_3\text{OH} \\
\text{CH}_3 & \quad \uparrow & \quad 55^\circ\text{C} & \quad \\
\end{align*}
\]

A) \(\text{CH}_2=\text{CH}–\text{CH}–\text{CH}_3\)
B) \(\text{CH}_3\)
C) \(\text{CH}_3–\text{CH}_2–\text{C}–\text{O}–\text{CH}_3\)
D) \(\text{CH}_3–\text{CH}_2–\text{C}=\text{CH}–\text{CH}_3\)
E) \(\text{CH}_3–\text{CH}_2–\text{CH}–\text{CH}_3\)

Ans.: C

20. Which compound would be the major product?
21. The major product of the following reaction would be:

\[
\text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_3 + \text{KCN} \xrightarrow{\text{CH}_3\text{OH/\ H}_2\text{O, 70}^\circ\text{C}} ?
\]

A) \[
\text{CH}_2=\text{CCH}_2\text{CH}_2\text{CH}_3
\]

B) \[
\text{CH}_3\text{CCH}=\text{CHCH}_3
\]

C) \[
\text{CN}
\]

D) \[
\text{CH}_3\text{CH}=\text{CHCH}_3
\]

E) \[
\text{OC}_2\text{H}_5\text{CH}_3
\]

Ans.: B
Additions

1. Select the reagents necessary to convert cyclopentene into cyclopentane.

A) H₂ and Ni
B) H₂O
C) Heat
D) Zn, H₃O⁺
E) Light

Ans.: A
Reaction Sequences: Nucleophilic Substitutions, Eliminations, Acid-Base Reactions, Additions

1. The structure of the product, C, of the following sequence of reactions would be:

\[ C_6H_5C≡CH \xrightarrow{\text{NaNH}_2, \text{liq. NH}_3} A \xrightarrow{\text{CH}_3\text{CH}_2\text{Er}} B \xrightarrow{\text{H}_2, \text{Ni}_2\text{B}[\text{P}-2]} C \]

A) \( \text{cis}-\text{CH}_3\text{CH}_2\text{CH}═\text{CHC}_6\text{H}_5 \)
B) \( \text{cis}-\text{CH}_3\text{CH}═\text{CHC}_6\text{H}_5 \)
C) \( \text{trans}-\text{CH}_3\text{CH}_2\text{CH}═\text{CHC}_6\text{H}_5 \)
D) \( \text{C}_6\text{H}_5\text{C}≡\text{CCH}_2\text{CH}_2\text{Br} \)
E) \( \text{C}_6\text{H}_5\text{C}≡\text{CCH}_2\text{CH}_3 \)

Ans.: A

2. Which of the following reactions would yield 2-pentyne?

A) \( \text{HC}≡\text{CH} \xrightarrow{\text{NaNH}_2} \text{CH}_3\text{CH}_2\text{CH}_2\text{I} \)
B) \( \text{CH}_3\text{C}≡\text{CH} \xrightarrow{1 \text{ mol NaNH}_2} \text{CH}_3\text{CH}_2\text{I} \)
C) \( \text{CH}_3\text{CH}CH\text{CH}_2\text{CH}_3 \xrightarrow{\text{Zn, CH}_3\text{CO}_2\text{H}} \)
D) \( \text{CH}_3\text{CH}_2\text{CHCH}_2\text{CH}_3 \xrightarrow{\text{HA, heat}} \)
E) \( \text{CH}_3\text{CH}CH\text{CH}_2\text{CH}_3 \xrightarrow{\text{NaOC}_2\text{H}_5} \text{C}_2\text{H}_5\text{OH} \)

Ans.: B

3. What sequence of reactions could be used to prepare the compound below from cyclopentane?

A) (1) \( \text{Cl}_2, \text{hv} \); (2) \( \text{t-BuOK/t-BuOH} \); (3) \( \text{OsO}_4 \); (4) \( \text{NaHSO}_3/\text{H}_2\text{O} \)

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4. Which of the following reactions would serve as a synthesis of butyl bromide?

A) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{HBr} \xrightarrow{\text{reflux}} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \]
B) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{PBr}_3 \xrightarrow{\text{reflux}} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \]
C) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{NaBr} \xrightarrow{\text{reflux}} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \]
D) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Br}_2 \xrightarrow{\text{reflux}} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \]
E) Answers A) and B) only

Ans.: A and B

5. Which would be the best way to carry out the following synthesis?

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \xrightarrow{?} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \]

A) (1) HA, heat; (2) H_3O^+, H_2O, heat
B) (1) (CH_3)_3COK / (CH_3)_3COH; (2) BH_3:THF, then H_2O_2, OH^-
C) (1) (CH_3)_3COK / (CH_3)_3COH; (2) H_3O^+, then H_2O, heat
D) (1) KOH, C_2H_5OH; (2) BH_3:THF, then H_2O_2, OH^-
E) (1) KOH, C_2H_5OH; (2) HA, heat; (3) H_3O^+, H_2O, heat

Ans.: B

6. *trans*-3-Methylcyclopentanol is treated with CH_3SO_2Cl in the presence of base. The product of this reaction is then heated with KI in methanol. What is the final product?

A) *trans*-1-Iodo-3-methylcyclopentane
B) *cis*-1-Iodo-3-methylcyclopentane
C) 1-Methylcyclopentene
D) 2-Methylcyclopentene
E) 3-Methylcyclopentene

Ans.: B

7. Which compound (or compounds) would be produced when *trans*-2-butene is treated first with
8. cis-3-Hexene is treated with magnesium monoperoxyphthalate and the product is then subjected to acid-catalyzed hydrolysis. What is the final product?

\[
\text{OH} \quad \text{HO} \quad \text{H} \\
\text{CH}_3\text{CH}_2\text{CCH}_2\text{CH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_2\text{C-CCH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_2\text{C-CCH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_2\text{C-CCH}_2\text{CH}_3
\]

(+ enantiomer)

A) I  
B) II  
C) III  
D) equal amounts, II and III  
E) IV  

Ans.: D

9. Epoxidation followed by reaction with aqueous base converts cyclopentene into which of these?

\[
\begin{align*}
\text{HO} & \quad \text{OH} & \text{HO} & \text{HO} \\
\text{I} & \quad \text{II} & \text{III} & \text{IV}
\end{align*}
\]

A) I  
B) II
10. Select the reagents necessary to convert 3-bromohexane into hexane.
A) Zn, H3O+
B) CuI
C) H2O
D) H3O+
E) OH−

Ans.: A

19. Provide reagents to convert an alkyl halide into an alkane

Ans.: (1) Mg, Et2O (2) H2O

22. Give the reaction conditions (reagents, solvent) to prepare a Grignard reagent.

Ans.: Mg, Et2O

23. Which would be the best way to carry out the following synthesis?

$\text{(CH}_3\text{)}_3\text{COH} \xrightarrow{?} \text{(CH}_3\text{)}_2\text{CHCH}_2\text{Br}$

A) (1) HA, heat; (2) HBr
B) (1) HBr and peroxides; (2) Br2/CCl4
C) (1) HA, heat; (2) HBr and peroxides
D) (1) Br2/CCl4; (2) HA, heat
E) (1) HA, heat; (2) Br2/CCl4

Ans.: C
Radical Reactions

1. Select the structure of the major product formed in the following reaction.

\[
\text{CH}_3 \quad \overset{\text{Br}_2}{\underset{h\nu}{\longrightarrow}} \quad \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \quad \text{V}
\]

Ans.: II

2. Which of these molecules is not expected to arise as a product of the high temperature chlorination of methane?
A) CCl\(_4\)
B) HCCl\(_3\)
C) CH\(_2\)Cl\(_2\)
D) CH\(_3\)CH\(_3\)
E) CH\(_2\)=CH\(_2\)

Ans.: E

3. In a competition reaction, equimolar amounts of five alkanes compete for a deficiency of chlorine at 300°C. The greatest amount of reaction would occur in the case of which of these alkanes?
A) Ethane
B) Propane
C) Butane
D) Isobutane
E) Pentane

Ans.: D

4. A chain reaction is one that:
A) involves a series of steps.
B) involves two steps of equal activation energy.
C) is one that can be initiated by light.
D) involves a series of steps, each of which generates a reactive intermediate that brings about the next step.
E) involves free radicals that have an unusual stability and thereby cause a large quantum yield.

Ans.: D

5. Which of the following gas-phase reactions is a possible chain-terminating step in the light-initiated chlorination of methane?
A) Cl–Cl $\rightarrow$ 2Cl·
B) Cl· + CH$_4$ $\rightarrow$ CH$_3$· + H–Cl
C) CH$_3$· + CH$_3$· $\rightarrow$ CH$_3$–CH$_3$
D) CH$_3$· + Cl–Cl $\rightarrow$ CH$_3$Cl + Cl·
E) More than one of the above

Ans.: C

6. The mechanism for a free-radical reaction consists of three types of steps. These are:

Ans.: initiation, propagation, termination – or chain-initiating, chain-propagating, chain-terminating
Conjugated Dienes

1. Which of the following compounds would be the most stable?

\[ \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \]

Ans.: I

2. Which compound would have the shortest carbon-carbon single bond?
A) \( \text{CH}_3-\text{CH}_3 \)
B) \( \text{CH}_2=\text{CH}-\text{CH}_3 \)
C) \( \text{HC}≡\text{C}≡\text{CH} \)
D) \( \text{CH}_2=\text{CH}-\text{C}≡\text{CH} \)
E) \( \text{CH}_2=\text{CH}–\text{CH}=\text{CH}_2 \)

Ans.: C

3. Which of the following dienes is a cumulated diene?
A) \( \text{CH}_2=\text{CHCH}_2\text{CH}_2\text{CH}=\text{CH}_2 \)
B) \( \text{CH}_2=\text{CHCH}=\text{CHCH}_2\text{CH}_3 \)
C) \( \text{CH}_2\text{CH}=\text{C}=\text{CHCH}_2\text{CH}_3 \)
D) \( \text{CH}_3\text{CH}=\text{CHCH}=\text{CHCH}_3 \)
E) \( \text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}_2 \)

Ans.: C

4. Ignoring stereochemistry, the 1:1 reaction of bromine with 1,3-cyclohexadiene at 25°C in the dark and in the absence of peroxide forms which of these?

\[ \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \]

Ans.: I and II

5. Systems that have a \( p \) orbital on an atom adjacent to a double bond are called ____________
systems.
Ans.: conjugated unsaturated

6. When the product distribution for a particular reaction reflects the relative stabilities of the products, the reaction is said to be under ____________ control.

Ans.: thermodynamic

7. What are the conditions necessary to be able to get either the thermodynamic or the kinetic product.

Ans.: reaction in equilibrium

8. Which diene and dienophile would you choose to synthesize the following compound?

Ans.: III

9. The following compound does not undergo the Diels-Alder reaction because:

A) ring systems cannot function as the diene component.
B) it cannot adopt the s-cis conformation.
C) it lacks electron-withdrawing groups.
D) it lacks strong electron-releasing groups.
E) the two double bonds are further apart than in a non-cyclic conjugated system.

Ans.: B

10. What would be the product of the following reaction?

\[
\begin{align*}
\text{I} & \quad \text{CH}_2=\text{CHCH}_3 \\
\text{II} & \quad \text{O} \\
\text{III} & \quad \text{heat} \\
\text{IV} & \quad \text{C-CH}_3
\end{align*}
\]

Ans.: III

11. Which of these conjugated dienes can undergo a Diels-Alder reaction?

\[
\begin{align*}
\text{I} & \quad \text{CH}_2 \\
\text{II} & \quad \text{II} \\
\text{III} & \quad \text{III} \\
\text{IV} & \quad \text{(CH}_3\text{)}_3\text{C} \\
\text{V} & \quad \text{C-CH}_2 \quad \text{C(CH}_3\text{)}_3
\end{align*}
\]

Ans.: III

12. Which diene and dienophile would you choose to synthesize the following compound?

\[
\begin{align*}
\text{I} & \quad \text{COCH}_3 \\
\text{II} & \quad \text{O} \\
\text{III} & \quad \text{O} \\
\text{IV} & \quad \text{C-CH}_2=\text{CH-COOCH}_3
\end{align*}
\]

Ans.: III
Aromatic Chemistry

1. Which is the best prediction of the site(s) of substitution when this compound is nitrated?

Ans.: 4 and 6

2. What feature is common to all meta-directing groups?
   A) The atom directly attached to the ring has a full or well-developed partial positive charge.
   B) The atom directly attached to the ring is doubly bonded to oxygen.
   C) One or more halogen atoms are present in the group.
   D) One or more oxygen atoms are present in the group.
   E) The group is attached to the ring through a carbon atom.

Ans.: A

3. What are the main limitations of Friedel Crafts Alkylation?

Ans.: Rearrangement and polyalkylation

4. Which annulene would you NOT expect to be aromatic?
   A) [6]-Annulene
   B) [14]-Annulene
   C) [16]-Annulene
   D) [18]-Annulene
   E) [22]-Annulene

Ans.: C

5. Which of the following structures would be aromatic?

Ans.:
Ans.: II

6. On the basis of molecular orbital theory and Hückel's rule, which molecules and/or ions should be aromatic?

- [Diagram of molecules and ions]

Ans.: IV, VI, VII and IX

7. In which case is the indicated unshared pair of electrons NOT a contributor to the $\pi$ aromatic system?

- [Diagram of molecules and ions]

Ans.: II

8. Which is the only one of these reagents which will react with benzene under the specified conditions?
   A) Cl$_2$, FeCl$_3$, heat
   B) H$_2$, 25°C
   C) Br$_2$/CCl$_4$, 25°C, dark
   D) KMnO$_4$/H$_2$O, 25°C
   E) H$_3$O$^+$, heat

Ans.: A

9. Consider the molecular orbital model of benzene. In the ground state how many molecular orbitals are filled with electrons?

Ans.: 3

10. In the molecular orbital model of benzene, how many pi-electrons are delocalized about the
11. Why would 1,3-cyclohexadiene undergo dehydrogenation readily?
A) It is easily reduced.
B) Hydrogen is a small molecule.
C) 1,3-Cyclohexadiene has no resonance energy.
D) It would gain considerable stability by becoming benzene.
E) It would not undergo dehydrogenation.

Ans.: D

12. Cyclopentadiene is unusually acidic for a hydrocarbon. An explanation for this is the following statement.
A) The carbon atoms of cyclopentadiene are all sp²-hybridized.
B) Cyclopentadiene is aromatic.
C) Removal of a proton from cyclopentadiene yields an aromatic anion.
D) Removal of a hydrogen atom from cyclopentadiene yields a highly stable free radical.
E) Removal of a hydride ion from cyclopentadiene produces an aromatic cation.

Ans.: C

13. The major product(s), B, of the following reaction would be:

\[
\begin{align*}
\text{HNO}_3 & \quad \text{H}_2\text{SO}_4 \quad \Delta \\
\text{CO}_2\text{H} & \quad \text{H}_2\text{CO}_2\text{H} & \quad \text{B} \\
\text{CO}_2\text{H} & \quad \text{CO}_2\text{H} & \quad \text{CO}_2\text{H} \\
\text{NO}_2 & \quad \text{NO}_2 & \quad \text{C}_2\text{O}_2\text{H} \\
\text{CO}_2\text{H} & \quad \text{C}_2\text{O}_2\text{H} & \quad \text{CO}_2\text{H} \\
\text{I} & \quad \text{II} & \quad \text{III}
\end{align*}
\]

A) I
B) II
C) III
D) Equal amounts of I and II.
E) Equal amounts of I, II and III.
14. What would you expect to be the major product obtained from the following reaction?

\[
\begin{align*}
\text{NO}_2 \quad \text{SO}_3\text{H} \\
\text{Br} \\
\text{NO}_2 \quad \text{SO}_3\text{H} \\
\text{Br} \\
\text{NO}_2 \quad \text{SO}_3\text{H}
\end{align*}
\]

\[
\begin{align*}
\text{Br}_2 \quad \text{FeBr}_3 \\
? \\
\text{Br} \\
\text{NO}_2 \quad \text{SO}_3\text{H}
\end{align*}
\]

A) I  
B) II  
C) III  
D) Equal amounts of II and IV.  
E) IV

Ans.: C

15. What would you expect to be the major product obtained from the following reaction?
16. Which of the following reactions would give the product(s) indicated in substantial amounts (i.e., in greater than 50% yield)?

\[ \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \quad \text{V} \]

A) I  
B) II  
C) III  
D) IV  
E) V  

Ans.: E
B) II
C) III
D) All of these
E) None of these

Ans.: E

17. Which reagent(s) would you use to carry out the following transformation?

ethylbenzene \(\xrightarrow{}\) benzoic acid
A) \(\text{Cl}_2\), light, and heat
B) \(\text{Cl}_2\), \(\text{FeCl}_3\)
C) \(\text{KMnO}_4\), \(\text{OH}^-\), heat (then \(\text{H}_3\text{O}^+\))
D) \(\text{HNO}_3/\text{H}_2\text{SO}_4\)
E) \(\text{SO}_3/\text{H}_2\text{SO}_4\)

Ans.: C

18. Which reagent(s) would you use to carry out the following transformation?

toluene \(\xrightarrow{}\) benzyl bromide
A) \(\text{Br}_2\), \(\text{FeBr}_3\)
B) \(\text{N}-\text{Bromosuccinimide, ROOR, } h\nu\)
C) \(\text{HBr}\)
D) \(\text{Br}_2/\text{CCl}_4\)
E) \(\text{NaBr, H}_2\text{SO}_4\)

Ans.: B

19. Starting with benzene, the best method for preparing p-nitrobenzoic acid is:
A) \(\text{HNO}_3/\text{H}_2\text{SO}_4\); then \(\text{CH}_3\text{Cl/AlCl}_3\); then separation of isomers; then \(\text{KMnO}_4/\text{OH}/\text{heat, followed by } \text{H}_3\text{O}^+\).
B) \(\text{CH}_3\text{Cl/AlCl}_3\); then \(\text{HNO}_3/\text{H}_2\text{SO}_4\); then separation of isomers; then \(\text{KMnO}_4/\text{OH}/\text{heat, followed by } \text{H}_3\text{O}^+\).
C) \(\text{CH}_3\text{Cl/AlCl}_3\); then \(\text{KMnO}_4/\text{OH}/\text{heat, followed by } \text{H}_3\text{O}^+\); then \(\text{HNO}_3/\text{H}_2\text{SO}_4\).
D) \(\text{HNO}_3/\text{H}_2\text{SO}_4\); then \(\text{KMnO}_4/\text{OH}/\text{heat, followed by } \text{H}_3\text{O}^+\); then \(\text{CH}_3\text{Cl/AlCl}_3\).
E) \(\text{HNO}_3/\text{H}_2\text{SO}_4\); then \(\text{CO}_2\), followed by \(\text{H}_3\text{O}^+\).

Ans.: B
20. A good synthesis of the following compounds would be:

\[ \text{(CH}_3\text{)}_3\text{C} - \text{O} - \text{CH}_3 \]

A) 
\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{CH}_3\text{CCl}} \text{AlCl}_3 & \rightarrow & \text{(CH}_3\text{)}_3\text{CCl} \\
& & & \text{AlCl}_3 \\
\end{align*}
\]

B) 
\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{(CH}_3\text{)}_3\text{CCl}} \text{AlCl}_3 & \rightarrow & \text{CH}_3\text{CCl} \\
& & & \text{AlCl}_3 \\
\end{align*}
\]

C) 
\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{CH}_3\text{CCl}} \text{AlCl}_3 & \rightarrow & \text{(CH}_3\text{)}_2\text{C}=\text{CH}_2 \\
& & & \text{HF} \\
\end{align*}
\]

D) More than one of these
E) None of these

Ans.: B

21. Which would be a good synthesis of \textit{m}-nitrobenzoic acid?

A) 
\[
\begin{align*}
\text{Benzene} & \xrightarrow{\text{HNO}_3/\text{H}_2\text{SO}_4, \text{heat}} \rightarrow & \text{CH}_3\text{Cl} & \xrightarrow{\text{AlCl}_3} & (1) \text{KMnO}_4, \text{OH}^-, \text{heat} \\
& & & & (2) \text{H}_3\text{O}^+ \\
\end{align*}
\]

B) 
\[
\begin{align*}
\text{Toluene} & \xrightarrow{\text{HNO}_3/\text{H}_2\text{SO}_4, \text{heat}} & (1) \text{KMnO}_4, \text{OH}^-, \text{heat} \\
& & & & (2) \text{H}_3\text{O}^+ \\
\text{HNO}_3/\text{H}_2\text{SO}_4 & & & & \text{heat} \\
\end{align*}
\]

C) 
\[
\begin{align*}
\text{Toluene} & \xrightarrow{(1) \text{KMnO}_4, \text{CH}^-, \text{heat} } & (2) \text{H}_3\text{O}^+ \\
& & & \text{HNO}_3/\text{H}_2\text{SO}_4 & \text{heat} \\
\end{align*}
\]

D) More than one of the above
E) None of the above

Ans.: C
22. Which of the following compounds would be most reactive toward electrophilic substitution?

\[ \text{OH} \quad \text{CH}_3 \quad \text{Br} \]

A) I  
B) II  
C) III  
D) IV  
E) V

Ans.: A

23. Which of the compounds listed below would you expect to give the greatest amount of meta-product when subjected to ring bromination?

\[ \text{OH} \quad \text{C}=\text{O} \quad \text{NH}_2 \]

A) I  
B) II  
C) III  
D) IV  
E) V

Ans.: B
24. Which would be the best synthesis of the following compound?

\[
\begin{align*}
\text{CO}_2\text{CH}_3 & & \text{CO}_2\text{CH}_3 \\
\text{CO}_2\text{CH}_3 & & \text{CO}_2\text{CH}_3
\end{align*}
\]

A) I  
B) II  
C) III  
D) IV  
E) V

Ans.: II